Atlantic Oceanographic and Meteorological Laboratory
Laboratory Accomplishments

List 3-5 major accomplishments for your laboratory. If accomplishment occurred more than 2 years ago, cite recent progress. Please specify importance of accomplishment, who have been the major users and what has been the benefit to the taxpayer.

<u>Project: Understand and describe the Meridional Overturning Circulation</u>

The Meridional Overturning Circulation (MOC) is a major component of the global climate system responsible for a large contribution to meridional oceanic heat flux by the ocean. The MOC is characterized in the Atlantic Ocean by northward poleward flow of warm surface water, which is compensated for by southward flow of deep colder water. The Deep Western Boundary Current (DWBC) is the major conduit for the southward flow. Characterization of the properties of the mean and time dependent DWBC are necessary for validation of the numerical models that will be used to forecast long-term climate change. Monitoring of the DWBC is necessary to provide a measure of the intensity of the MOC. Paleo-climate studies have shown that the intensity of the MOC plays a major role in global climate and sustained observations of the DWBC can provide indicators for potentially dramatic climate variability (e.g., abrupt climate change). Observations collected at AOML along the western boundary of the North Atlantic have established that the DWBC is a continuous flow from the subpolar to the equatorial Atlantic. Time-series of the water mass characteristics of the DWBC off the Bahamas have demonstrated that advective times of the DWBC are considerably faster than found in earlier studiesThe importance of this discory are: (1) they provide characterizations of the present ocean climate, characterizations that must be simulated by climate forecast model to develop confidence in their predictions and (2) demonstrate that it is possible to monitor the DWBC with present technology. The second result provided the stimulus for sustained observations of the DWBC, a project being conducting cooperatively with British oceanographers to study abrupt climate change. This will reduce the cost of operations.

<u>Project: Understand and describe long-time scale signals in tropical storm formation</u>

Both the annual number of Atlantic tropical storms forming south of 23.5N and of Atlantic major hurricanes increased between the 1970's/1980's and 1995-2000. These increases are coincident with a multi-decadal warming in the North Atlantic SST suggesting that the high activity of 1995-2000 may persist for the next ~10 to 40 years. However, during 1950-2000 strong decadal oscillations are superimposed on the multi-decadal changes in both SST and tropical storms (positive SST anomalies in the main development region for storms, increased storm activity). We appear to be entering a negative phase of the decadal SST signal in the main development region for disturbances implying that tropical storm, and most likely major hurricane, activity may be reduced in the next several years rather than remain at the very high 1995-2000 level when both signals were in their positive phase. Tropical storm activity during 2001 and 2002 is less than expected from the multi-decadal signal, but for 2002 the main cause may be El Nino. Thus, if verified with future data, another variable to be considered in hurricane forecasting will be available. The importance of this discovery is that better forecast in the number of hurricanes and tropical storms will be provided.

Project: Global Carbon Cycle-

First data based inventory of anthropogenic CO2 in the ocean: In close collaboration with PMEL and academic collaborators through OGP's Ocean-Atmosphere Carbon Exchange Study (OACES) we have determined the first inventory of anthropogenic CO2 in the ocean based on observations, as opposed to models. The program commenced in the early 1990-ties in collaboration with DOE with measurements of referenced high quality carbon, nutrient and hydrographic parameters on the long lines under auspices of WOCE, JGOFS and OACES. At the completion of the field programs in 1998, NOAA/OGP sponsored an extensive data syntheses exercise led by scientists at AOML and PMEL where the data necessary for the determination of anthropogenic CO2 content (T, S, TCO2, Talk, NO3, O2, and CFC) were collated from over 70 cruises and quality assured with adjustments as necessary through exhaustive comparisons. Based on these high quality data sets, basin scale anthropogenic CO2 inventories were determined. We have found that cumulatively the worlds oceans have absorbed 112 Pg C of CO2 or 29 % of the excess CO2 produced by man's activities since the start of the industrial revolution. The synthesized data set has also been used to study global cycles of nutrient regeneration in the deep ocean and the remineralization of calcite, which will have a significant impact on the future sequestration capability of the ocean. The findings are critical for national and international assessments of the long-term fate of anthropogenic CO2, such as the IPCC report. The monetary value the annual sequestration of 2 Pg C by the ocean equates to a $ 4 billion dollar "service " . Monitoring future uptake is thus essential.

Representative publications:

Peng, T.-H., R. Wanninkhof, J. Bullister, R. Feely, and T. Takahashi, Quantification of decadal anthropogenic CO2 uptake in the ocean based on dissolved inorganic carbon measurements, Nature, 396, 560-563, 1998. OAR paper of the year award 1999
Lee, K., S.-D. Choi, G.-H. Park, R. Wanninkhof, T.-H. Peng, R.M. Key, C.L. Sabine, R.A. Feely, J.L. Bullister, and F.J. Millero, An Updated Anthropogenic CO2 Inventory in the Atlantic Ocean, Global Biogeochem. cycles, accepted, 2003.

Project: Climatology of air-sea CO2 fluxes: The rate at which the ocean takes up CO2 directly affects projections of future atmospheric CO2 levels.

Under the lead of Takahashi of LDEO we produced the first climatology of surface ocean pCO2 levels and the CO2 fluxes inferred from these levels. AOML and PMEL were the first laboratories in the US to permanently install automated underway systems to measure pCO2 in surface water on (NOAA) research ships and have operated the systems for the last decade. This dataset constituted a significant portion of the input for the monthly pCO2 climatology. Scientists at AOML perfected relationships between gas exchange and wind speed based on theory and dedicated field studies. The gas exchange parameterization is necessary to convert surface water pCO2 levels to CO2 fluxes. The pCO2 climatology is widely considered the most important contribution to oceanic and atmospheric carbon cycle studies in the last decade and is used extensively as a boundary or constraint in models, as a baseline for CO2 flux anomalies resulting from, for instance, ENSO processes. Aside from the need to constrain the fluxes to predict future atmospheric levels rising surface CO2 concentrations are believed to have detrimental effect on coral ecosystems. Sustained monitoring is thus imperative.

Project: Improve the prediction of tropical cyclone tracks by enhancing understanding of the interactions between a tropical cyclone and its environment through an optimal analysis of field observations:

Since 1997, the Tropical Prediction Center and the Hurricane Research Division have conducted operational synoptic surveillance missions with a Gulfstream IV-SP jet aircraft to improve numerical forecast guidance. Due to limited aircraft resources, HRD developed optimal observing strategies for these missions. Three dynamical models were employed in testing the targeting and sampling strategies. Target areas are represented by areas of large forecast spread in the NCEP bred-vector ensemble forecasting system. Assimilation of only the subset of data from the subjectively-found fully sampled target regions (generally encompassing between one-third and two-thirds of all the data) produced a statistically significant reduction of the track forecast errors of up to 25% within the critical first two days of the forecast. This is comparable with the cumulative business-as-usual improvement expected over eighteen years. This is the first effort to show that carefully selected targeted observations are better than gathering large amounts of regularly-spaced data. The results of this work were used to justify the Taiwanese starting the second operational tropical cyclone surveillance program in the world.

Project: Advance the prediction of tropical cyclone structure and intensity change by improving understanding of internal storm dynamics and storm interactions with the atmosphere and ocean:

A. In the past, the lack of direct measurements at and near the surface in the eyewall of hurricanes prevented meteorologists from accurately determining a hurricane's maximum wind speeds, especially just prior to landfall. Surface wind speed estimates are used by the Tropical Prediction Center (TPC) and emergency managers to decide the extent of warnings and evacuations in advance of a hurricane and, by the insurance community. AOML scientists were instrumental in developing the GPS dropwindsonde and a new observational strategy that used this device to obtain the first detailed measurements of low-level hurricane eyewall winds. As a result of this work, scientists are now able to measure hurricane eyewall winds with far greater accuracy and detail than in the past.

B. AOML scientists published a breakthrough description of a storm’s vertical wind speed structure and its relation to the tumultuous ocean surface below the storm. This new characterization could affect numerous computer models used to predict hurricane motion, intensity, and the associated waves and storm surge that can be devastating to near shore communities. New data collected from Global Positioning System (GPS) dropwindsondes provide information about the force the wind exerts on the sea surface, information that was previously difficult to measure and thus extrapolated from much weaker storms. Because the hurricane environment is too severe for conventional sensors, these are the first drag coefficient, stress, and roughness measurements to have been made in hurricanes. These results suggest that revisions are necessary for momentum flux parameterizations currently used in almost all numerical forecast models for a variety of disciplines including prediction of weather, storm surge, waves, and associated risk.

C. The intensification of a hurricane involves a combination of different favorable atmospheric and oceanic conditions. Hurricane Opal (1995) rapidly intensified as it passed over a strong oceanic warm core ring, indicating that the ocean may play a more important role in intensity change than previously thought. Several experiments carried out in Opal investigated air-sea heat exchange processes. New methodologies utilizing remotely sensed sea surface altimetry and very high resolution radiometry were developed. These procedures provide scientists another tool for forecasting hurricane intensity, particularly in the Gulf of Mexico. Monitoring the upper oceanic thermal structure is now a key observation element in the rapid intensification of hurricanes. It has also become a guidance tool for prediction of tropical cyclone intensification at NHC.